NASA-CR-199123

FINAL
7N-35-CR
OCIT.
63069
P-16

Final Report for NASA/Goddard Space Flight Center

Grant (NAG 5-790)

"Studies in Support of Remote Sensing Gamma-Ray Spectrometer"

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August 16, 1995

(NASA-CR-199123) STUDIES IN SUPPORT OF REMOTE SENSING GAMMA-RAY SPECTROMETER Final Report (Arizona Univ.) 16 p

N95-71573

Unclas

Z9/35 0063069

We have completed our work on the subject grant. We studied the effect of temperature on several different scintillators that are suggested for use in planetary gamma-ray spectrometry. These scintillators are important because they are much easier to accommodate on planetary missions than the much better performing solid-state sensors that were used on the Mars Observer mission.

We have shown that the scintillators Bismuth Germanate (BGO) and Gadolinium Orthosilicate (GSO) both improve at lower temperatures. Figures showing these results are included in the attached appendix which is from a presentation made at a June 20 PIDDP meeting run by Jack Trombka of GSFC, the PI on the Gamma-ray instrument development program.

The figures show that the resolution of the BGO continues to improve down to a temperature of about -100° C after which it levels out to show little effect of improved performance at lower temperature. The resolution of GSO improves slightly at lower temperature, reaches a minimum (best resolution) between -25° C and -50° C and then gets worse at still lower temperature.

The absolute values of the resolution are not nearly so good as are typically found in the literature. One of the reasons for this is that we wanted to be sure to isolate any changes in the scintillator with temperature from possible effects of cooling the photomultiplier tube (PMT). The setup is shown in the attached appendix. We isolated the PMT from the scintillator crystal with a long piece of lucite acting as a light pipe. Although we wrapped the light pipe in reflective Teflon, we clearly lost some light collection efficiency in the process, which led to the poorer than normal resolution. Nevertheless, the results should be useful for finding relative performance and the optimum temperature of operation.

Conclusions

Both BGO and GSO can be used in planetary missions and will show improved performance at lower temperatures. Many missions anticipated for the future will be to small bodies with an ambient temperature that is less than 25° C, and thus it will be easy to cool the scintillators. In particular, the BGO scintillator, which continues to improve down to about 170 K, and does not get worse at still lower temperatures, might be ideal for a comet mission since most short-period comets are expected to have ambient temperatures in the range of 120 to 150 K.

APPENDIX

PIDDP Progress and Future Work

June 20, 1995

William Boynton
University of Arizona

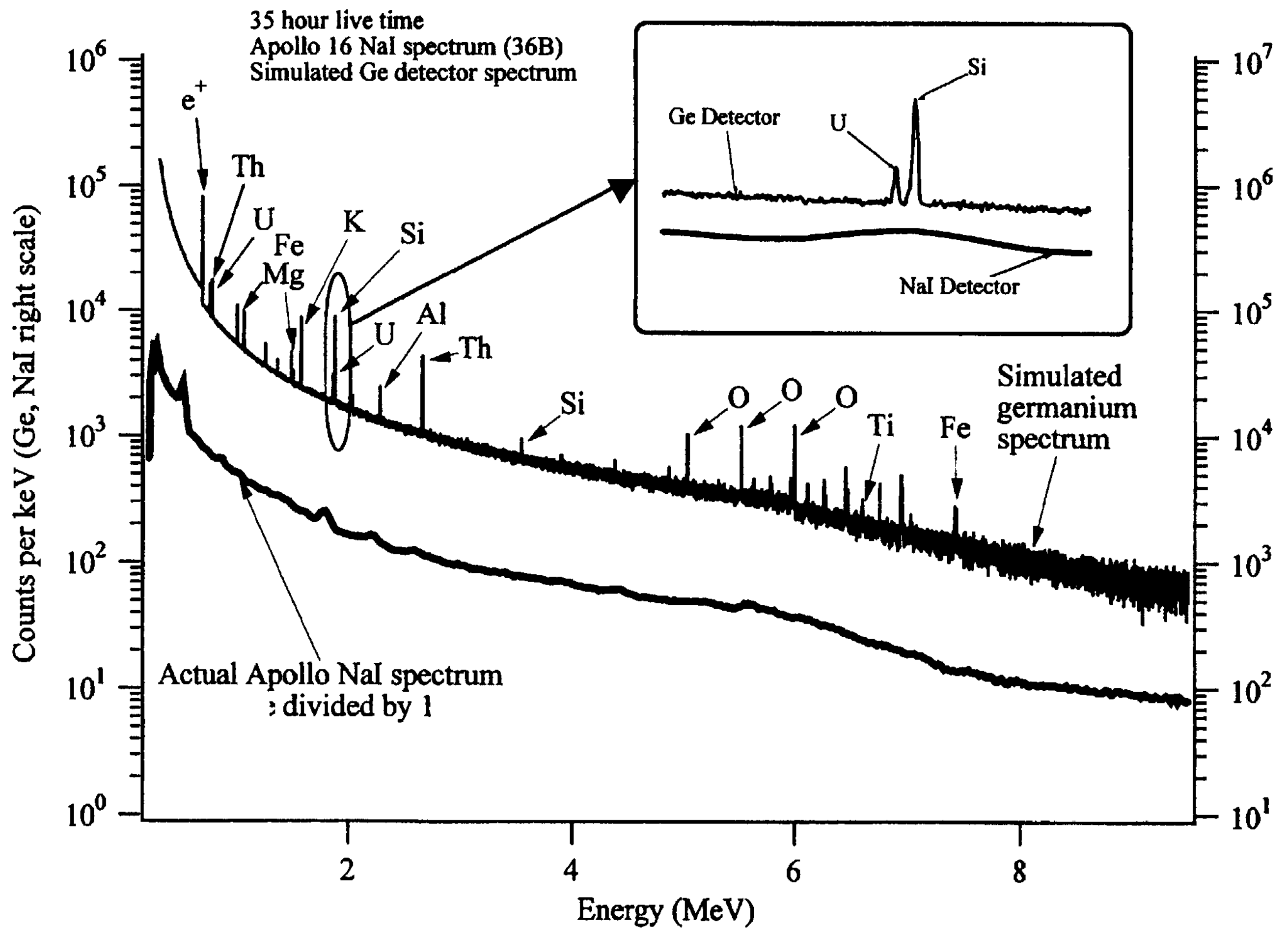
Alternate Simpler Cheaper Technology?

- Old technology used scintillator-based detectors
  - These were used in the laboratory until about 30 years ago when Ge detectors became common
  - They were used for the Apollo GRS investigation
  - The Soviets have flown them to Venus and Mars
- Scintillator-based gamma-ray detectors are (nearly?) not worth flying to Mars
  - Spectral resolution of scintillators are much worse than that of Ge solid-state detectors
  - Data analysis is **MUCH** more complicated
  - Soviet Phobos CsI scintillator at Mars returned nearly no useful information

Scintillator-based GRS for Mars?

- Spectral resolution of scintillators is much worse than that of Ge
  - NaI resolution (7% FWHM) is about a factor of 30-50 worse than Ge
  - Bismuth Germanate (BGO) is about a factor of two worse than NaI
    - BGO has higher density, so it has better stopping power/unit volume
    - Per unit mass, however, it is comparable to NaI
    - BGO resolution improves with lower temperature
      - Best that Schlumberger has achieved is 11% FWHM
        - Still much worse than NaI
      - Variation with temperature will lead to gain drifts every orbit
      - Apollo NaI (not nearly so sensitive to temperature) drifted by 8%
  - CsI is intermediate in both resolution and stopping power.

Plot of Lunar NaI vs. Ge Spectrum

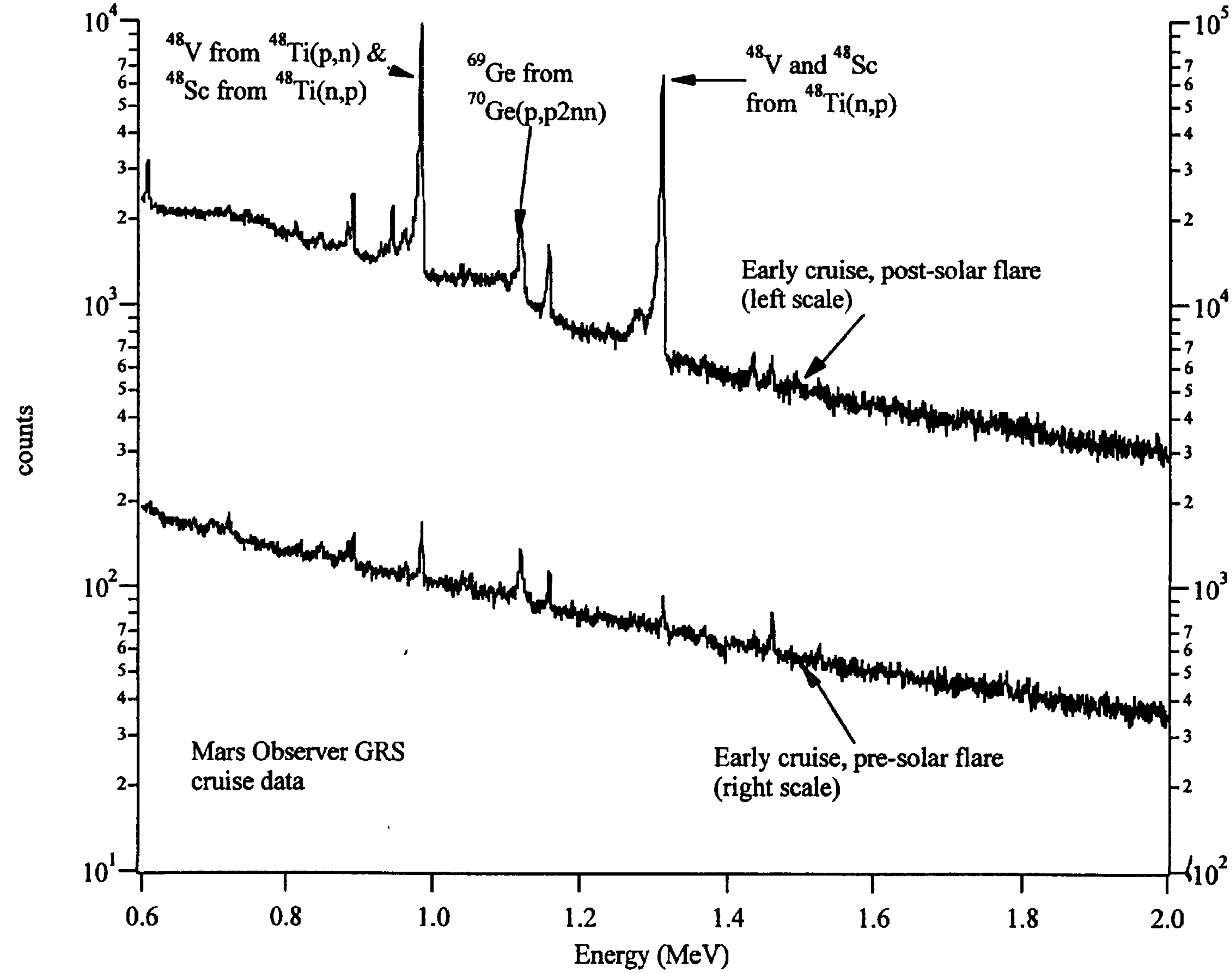


Scintillator-based GRS for Mars?

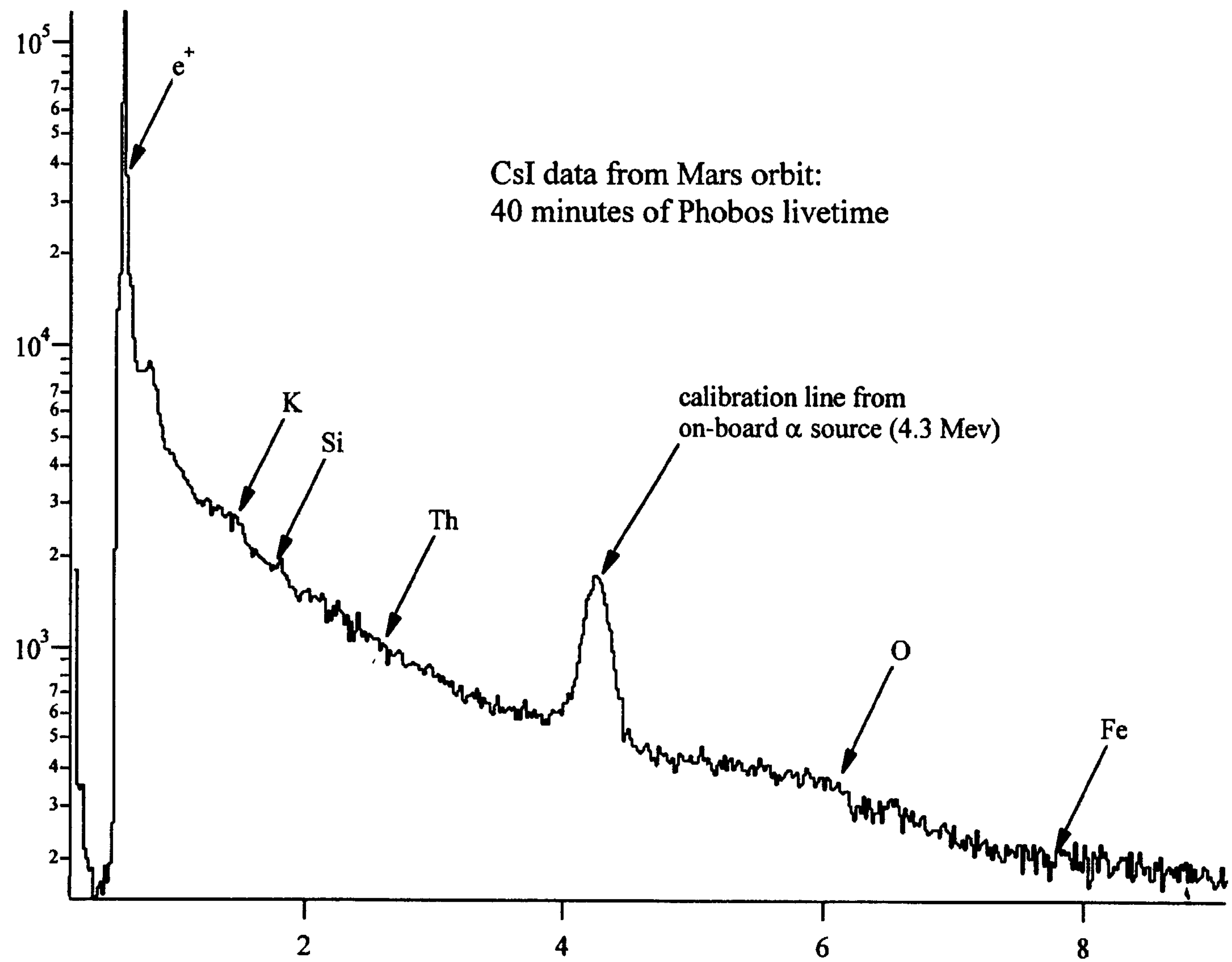
- Data Analysis is much more complicated
  - Apollo data not published in "final" form until 1976
    - Data continued to be refined for another five years thereafter.
  - Spallation causes radioactive species to grow in with time
    - Not so much of a problem for Apollo since their entire mission lasted only a few days
    - With a one-year cruise and a two-year mission, the radioactivity buildup for a Mars mission will be significant
    - Spallation on high-Z material (like bismuth, iodine, or cesium) can make many different nuclides with gamma rays all over the spectrum
    - Determining the peaks caused by spallation and learning how to correct for them will be a big job
  - Money saved in hardware would probably be lost in software and data-analysis cost
  - Data inversion requires that we know the hydrogen (water) content
    - With a scintillator, determination of hydrogen will be impossible
    - Even with a good neutron spectrometer, hydrogen content is very model dependent (as shown earlier) and will likely not be determined

PIDDP - GRS Presentation

Mars Observer Data Showing Spallation Lines



Mars Gamma-Ray Spectrum from Phobos CsI detector



Mars Elemental Concentrations from Phobos Data

Element	PC-3	PC-4
O (%)	40 ± 18	54 ± 27
Si (%)	11 ± 6	15 ± 7
Fe (%)	10 ± 4	4 ± 7
K (%)	0.2 ± 0.1	0.3 ± 0.2
Th (ppm)	3 ± 1	2 ± 1

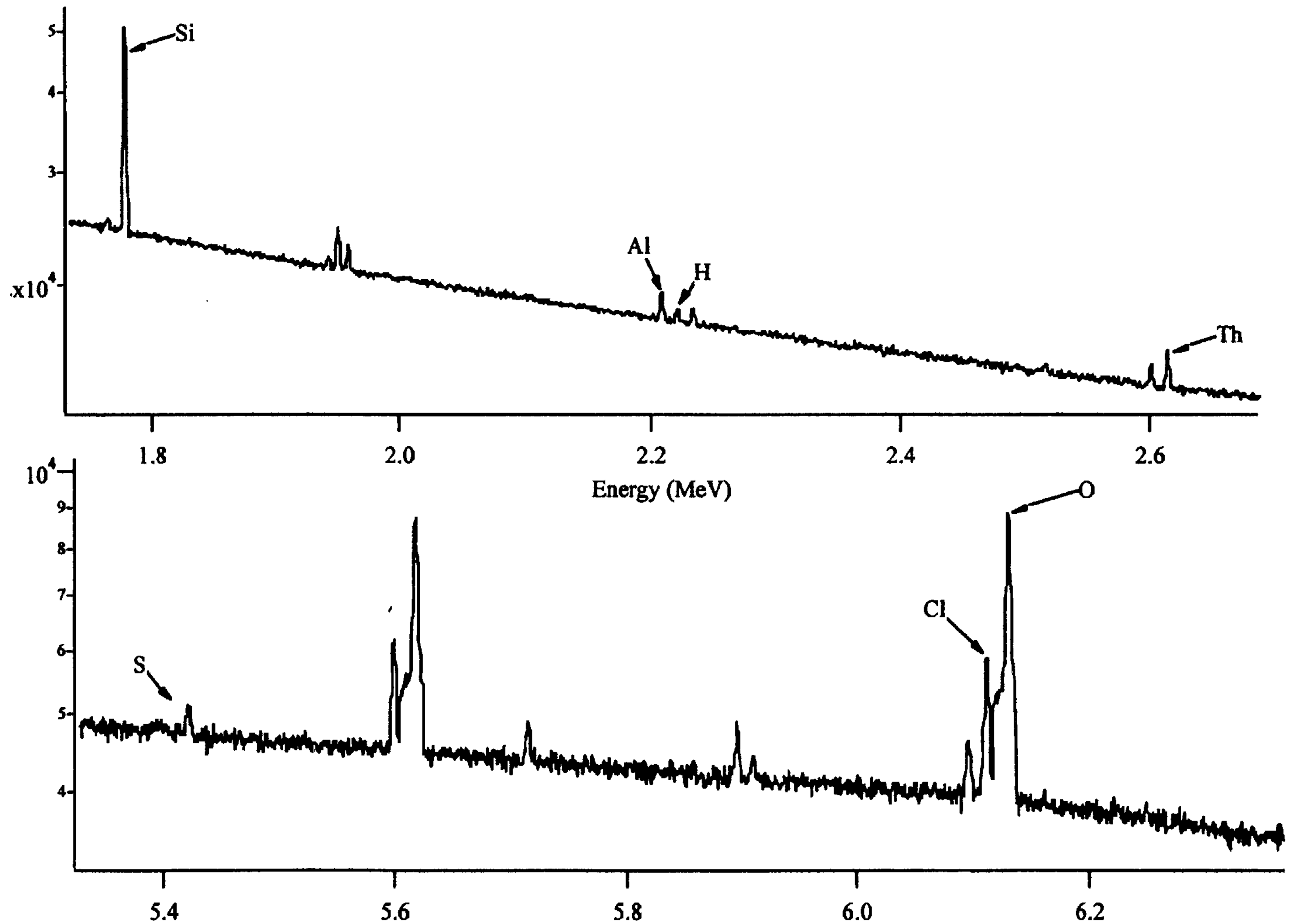
"The concentrations of O are consistent with expectations for silicate materials, but otherwise provide no particularly useful geochemical information."

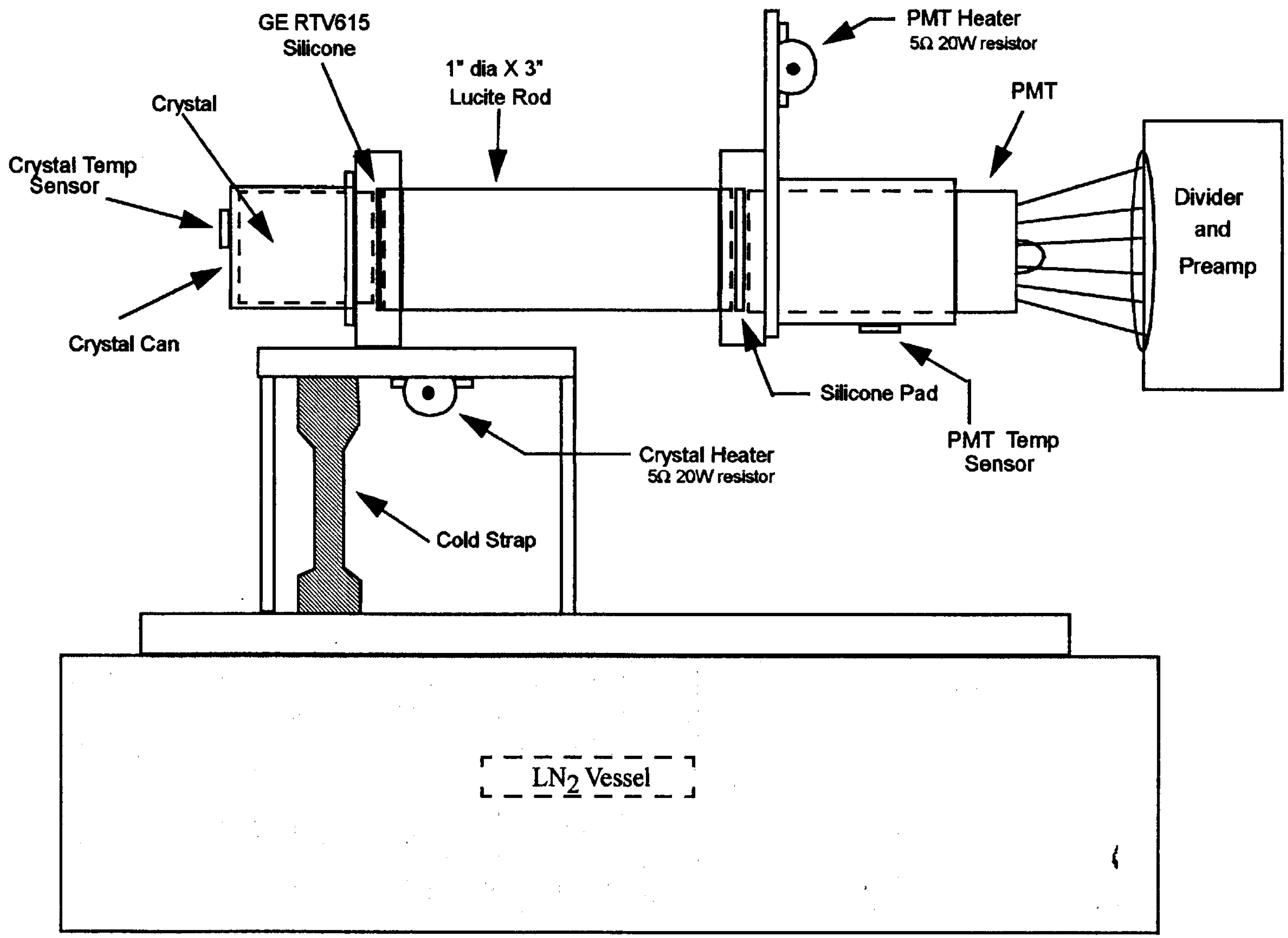
"...for Si..., the nominal values of 11% and 14.9% are too low for any plausible silicate material. The Si results therefore are also of questionable geochemical usefulness."

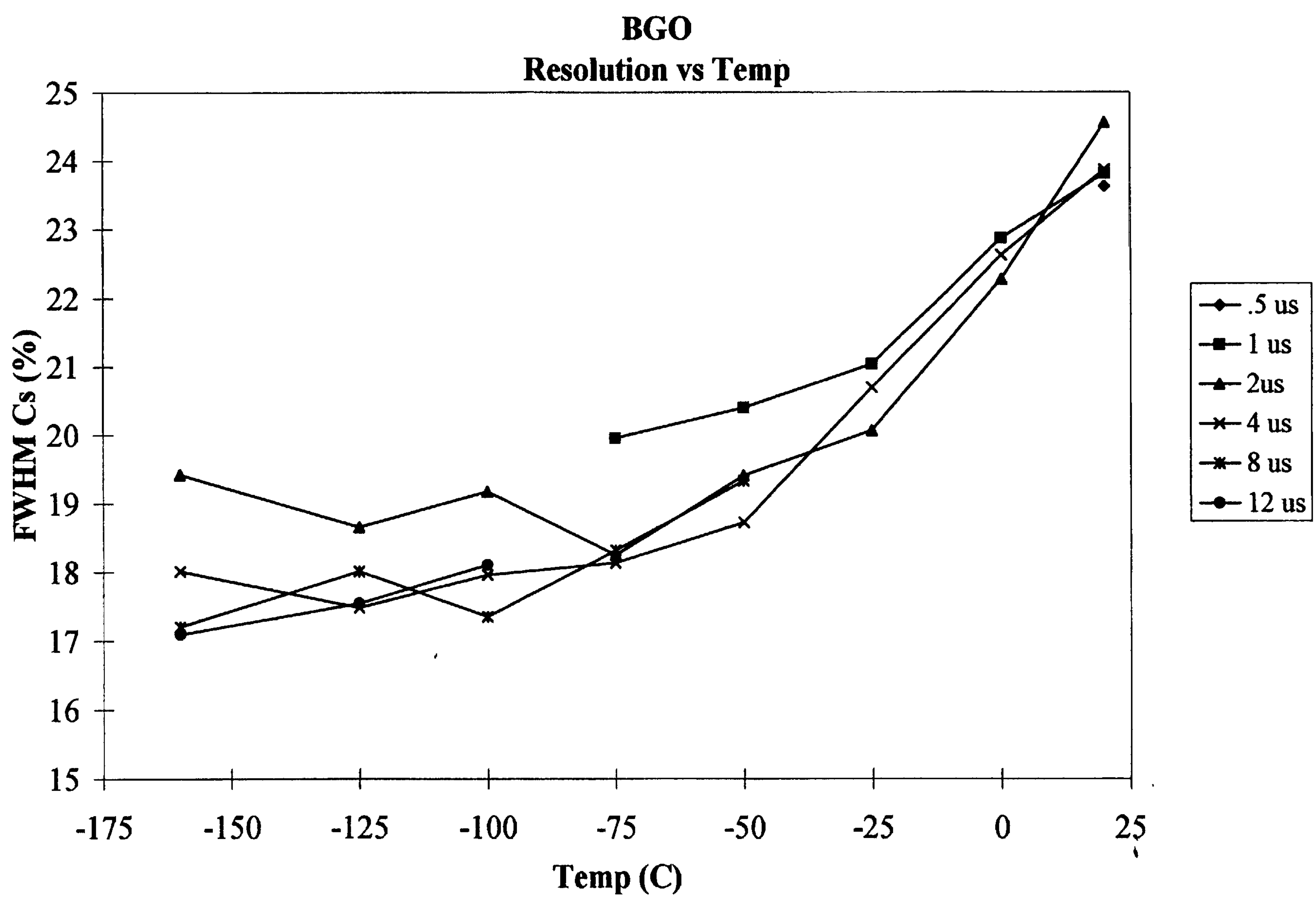
Data from two pericenter passes. (Trombka et al., 1992)

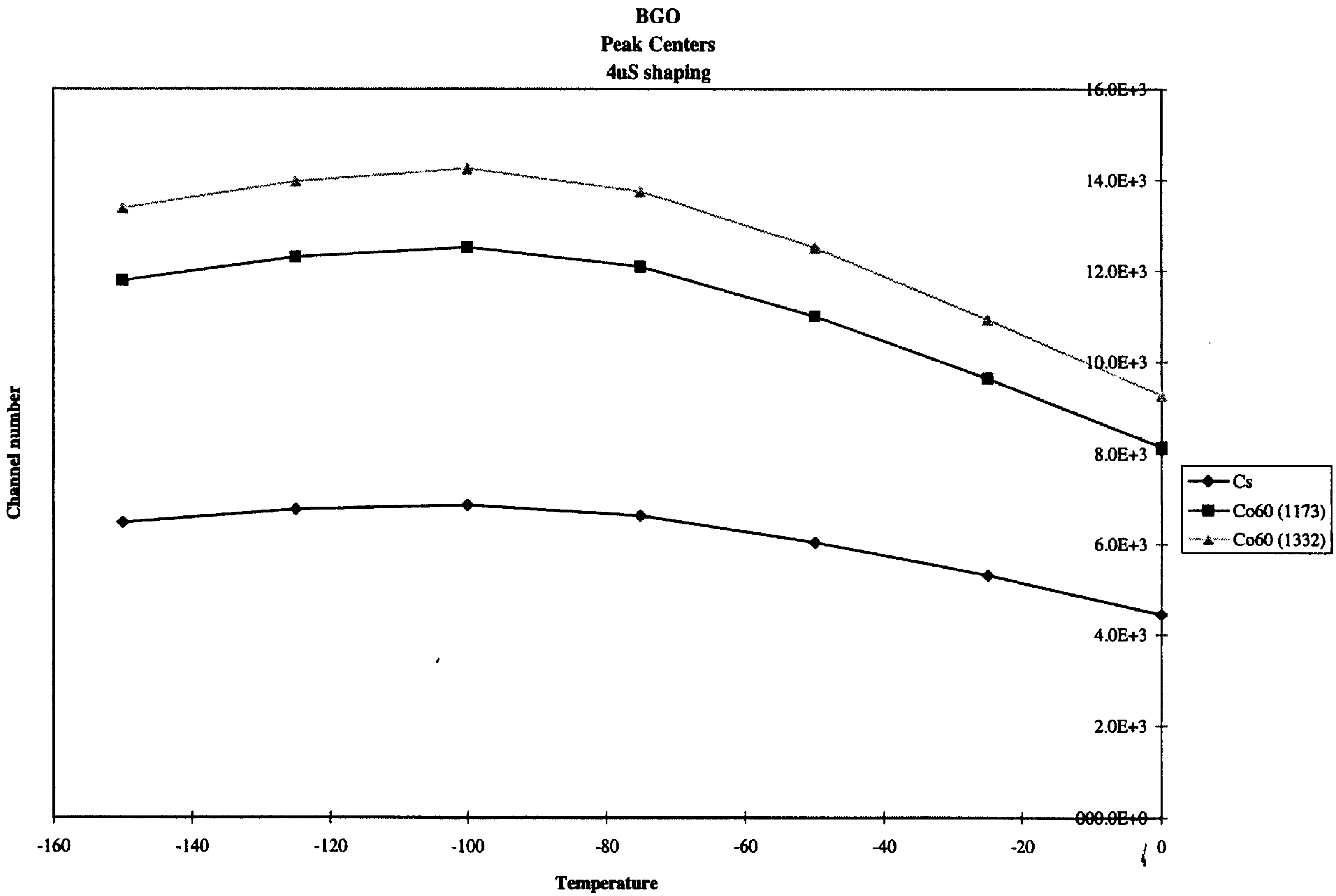
Scintillator-based GRS for Mars?

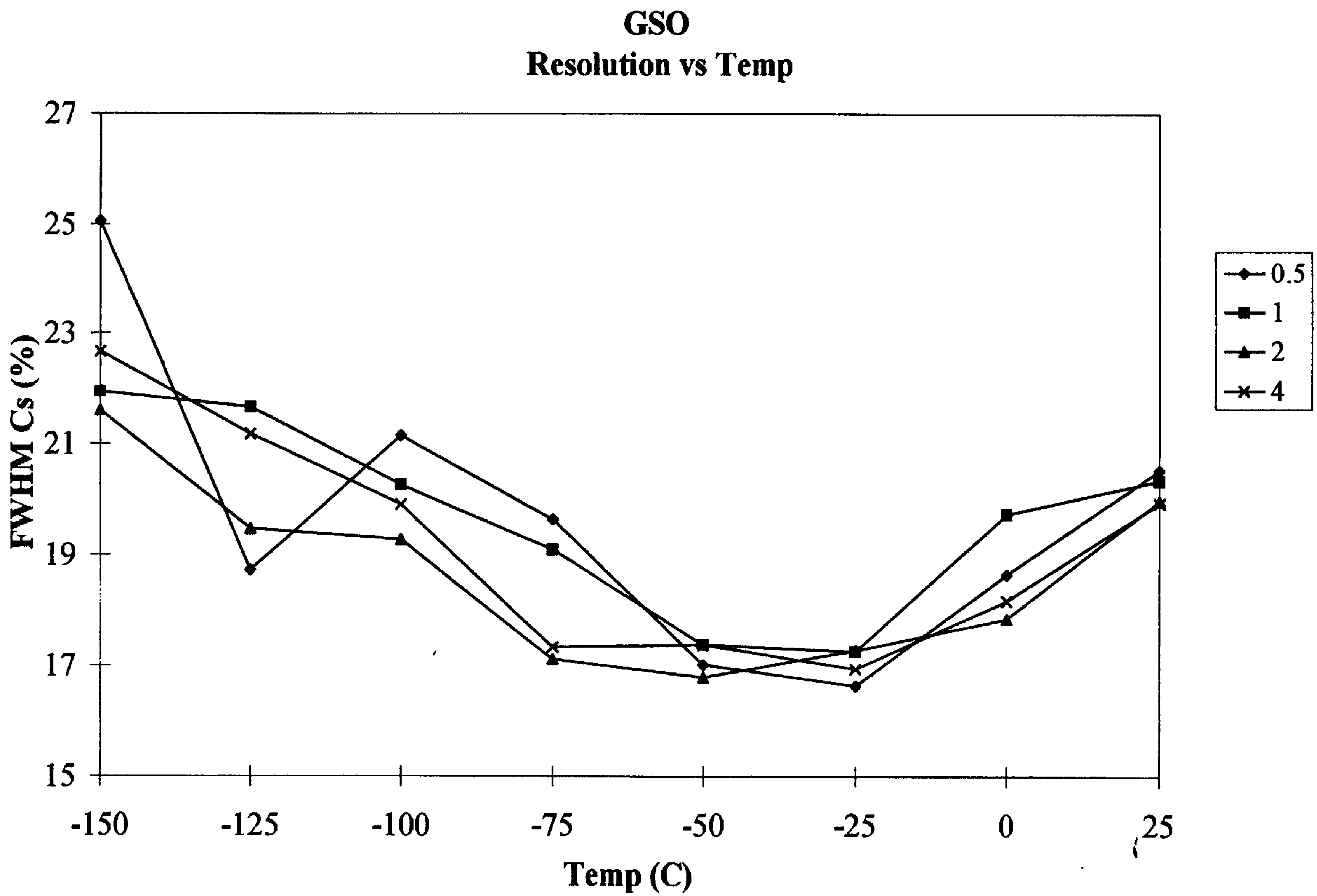
- Mars Ge simulation shows that it is essential to have a high resolution detector to determine volatile elements




GE RTV615
Silicone
1" dia X 3"
Lucite Rod
Crystal
Crystal Temp
Sensor
Crystal Can
PMT Heater
5Ω 20W resistor
PMT
Divider
and
Preamp
Silicone Pad
PMT Temp
Sensor
Crystal Heater
5Ω 20W resistor
Cold Strap
LN_2 Vessel


BGO
Resolution vs Temp
25
24
23
22
21
20
19
18
17
16
15
FWHM Cs (%)
-175
-150
-125
-100
-75
-50
-25
0
25
Temp (C)
.5 us
1 us
2us
4 us
8 us
12 us


BGO
Peak Centers
4uS shaping
Channel number
16.0E+3
14.0E+3
12.0E+3
10.0E+3
8.0E+3
6.0E+3
4.0E+3
2.0E+3
000.0E+0
-160
-140
-120
-100
-80
-60
-40
-20
0
Temperature
Cs
Co60 (1173)
Co60 (1332)


GSO
Resolution vs Temp
27
25
23
21
19
17
15
FWHM Cs (%)
-150
-125
-100
-75
-50
-25
0
25
Temp (C)
0.5
1
2
4